Canada Alberta

FOREST RESOURCE DEVELOPMENT AGREEMENT
ENTENTE SUR LA MISE EN VALEUR DES RESSOURCES FORESTIERES

Canada Alberta

88-00665/

The Canada-Alberta Forest Resource Development Agreement is a subsidiary agreement of the Canada-Alberta Economic and Regional Development Agreement, which provides coordination and cooperation between the governments of Alberta and Canada in areas of Alberta's economic development.

The Canada-Alberta Forest Resource Development Agreement is funded equally by the governments of Canada and Alberta, from April 1, 1984, to March 31, 1989.

Its primary objectives are to ensure the long-term availability of timber supplies; to optimize timber uses; and to contribute to the growth and diversification of Alberta's economy.

The Agreement comprises three programs: Reforestation; Applied research, technology transfer and opportunity identification; and Public information, evaluation and administration. These programs are managed by a joint Directorate and are implemented by the Canadian Forestry Service and the Alberta Forest Service.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est auxiliaire à l'Entente Canada-Alberta sur le développement économique et régional, qui vise à assurer la coordination et la coopération des deux gouvernements relativement au développement économique de l'Alberta.

L'Entente Canada-Alberta sur la mise en valeur des ressources forestières est financée à parts égales par les gouvernements du Canada et de l'Alberta, et a cours du 1er avril 1984 au 31 mars 1989.

Ses objectifs principaux sont assurer la disponibilité à long terme de réserves de bois; optimiser leur utilisation; et contribuer à la croissance et la diversification de l'économie de la province.

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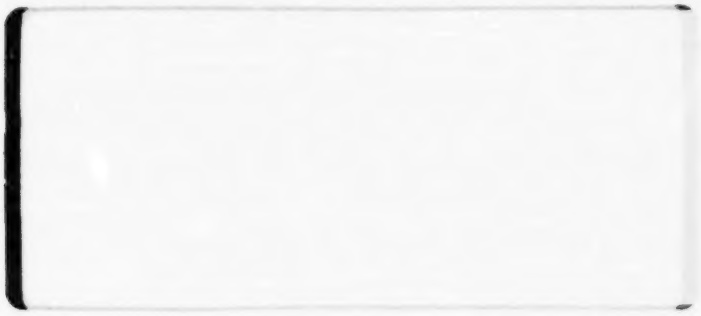

For more information, please call or write:

Pour de plus amples informations, veuillez vous adresser à:

Canadian Forestry Service
Northern Forestry Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5
Telephone: (403) 435-7210
Attention: S. Price

OR/OU Alberta Department of
Forestry, Lands & Wildlife
9915 - 108 Street
Edmonton, Alberta
T5K 2C9
Telephone: (403) 427-3583
Attention: D. Fregren

TECHNICAL REVIEW ON THE STATE-OF-THE-ART OF DIMENSIONAL STABILIZATION OF WOOD PRODUCTS USING CHEMICAL IMPREGNATION

Bidhi Singh Bains, Ph.D.[1]
Wood Research Ltd. 1986

This is a joint publication of the Canadian Forestry Service
and the Alberta Forest Service pursuant to the
Canada-Alberta Forest Resource Development Agreement

[2]Edmonton, Alberta

DISCLAIMER

The study on which this report is based was funded under the Canada-Alberta Forest Resource Development Agreement.

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ISBN 0-662-15333-2

Catalogue No. Fo 42-91/11 - 1987E

Additional copies of this publication are available at no charge from:

Regional Development
Canadian Forestry Service
5320 - 122 Street
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SUMMARY

This report is a compilation of ealier work in the field of dimensional stabilization of wood. The emphasis is given on the suitable water soluble acrylic (self-crosslinking & thermoplastic), glyoxal polymers (reactive) formulations and their blends. The shrinking and swelling of wood in polar and non-polar solvent, the entrapment of polymer and solvent in wood structure is also discussed. The quanity of polymers required for dimensional stabilization depend on the end use of the products. The chemical costing of treatment is calculated from the performace results of earlier investigators and it reflects the tentative polymer requirement for dimensional stabilization of wood products. This costing may vary with the end use of the products.

OBJECTIVES

1. Litrature review
   a. Chemical impregantion of wood products with dimensional stabilizing chemicals.
   b. State-of-art of dimensional stabilization of wood
2. Economic feasibility of the polymer treatment.
3. Expected Scope of process and Technology

LITERATURE REVIEW

1. Flow of a Fluid in Wood

A solution penetrates into the capillary structure of wood by bulk flow, diffusion flow or their combination (Cote 1983). The bulk flow is a forced flow under specific conditions such as pressure impregnation of wood chips by cooking chemicals, wood impregnation by preservative chemicals and monomers impregnation of wood for *in situ* polymerization. On the other hand, diffusion has its association with, (a) air drying or kiln drying of wood, (b) moisture migration of wood in use, and (c) impregnation of green wood with water soluble chemicals and so on.

The movement of moisture in wood is governed by bound water diffusion & intergas diffusion and the bulk flow is always associated with both the above type of diffusions flows. The swelling and shrinking of the wood occur below the fiber saturation point when cell cavities are almost empty. The water vapors are transferred by intergas diffusion through empty or partially filled wood cell lumens. On drying or seasoning of the wood, the bodered pit membranes are sealed and bulk flow cannot go on, however the diffusion mechanisms are still operative for the transportation of moisture. The dried cell sap of most woods are water soluble, that is by the water soluble and polar solvent based chemicals solutions have better edge on non-polar solvent

based chemical formulations for chemical impregnation of wood.

2. Chemical Impregnation of Wood

2.1 Solid Wood:

Wood in green or partially dried condition above the fiber saturation point is a good choice for treatment with diffusion processes. The wood to be treated is submerged down in container of treating solution, keeping an extra solution head at the top. Practically, the diffusion treatments are a combination of bulk flow, bound water diffusion and intergas diffusion (called as aided diffusion). The most specific requirement for the treatment is the moisture of wood. These treatments are never successful, if the wood is dried below fiber saturation point so as the pore size of the capillaries become smaller than the molecule size of the impregnating chemicals.

The diffusion impregnation are also effected by other factors like, (a) concentration of the chemical in solution, (b) viscosity of solution, (c) temperature and (d) time of treatment. The viscose solution are filtered out at the surface of wood and the wood under treatment pickup more solvents. In addition to that there is always a concentration gradient in treated wood under diffusion processes, i.e. the surface of wood has more dry chemicals than the inside.

The dried wood is usually pressure treated in treating cylinder. Sometime, the green wood is also pressure treated where its moisture is lowered by pre-steaming. Here, the pre-steaming has double action, (a) it lowers the moisture content, and (b) it increases the porisity of wood.

Comparing the two types of treatment processes, impregnation by diffusion is a slow process, but it is promising as the treatment is more smooth in the cell-walls structure of wood.

2.2 Wood Particles:

The water soluble chemicals are easily penetrated into thin wood members (chips, wood wool, veneers, shingles and shakes etc.). The chemical solution is applied in spray tunnels or deluging or in rotary drum mixer. The treating solution adhere to wood surface and later on get penetrated by diffusion and negative pressure built up in capillaries structure of wood.

Usually, the thin particals of wood act as reinforcement materials and are binded with some resin, cement or clay, as in acoustic boards, partical boards and plywood. The nature of first impregnated chemical has remarkable impact on the incoming binder chemicals. The following precaution may be kept in mind while selecting second chemical as binder,

1. The first chemical should be dried to temporary crosslink with the functional groups of the wood.
2. The incoming binder should have same chemical nature, i.e. the curing pH for both the polymers should be same.
3. The temperature of curing for both the polymer should be of the same range.
4. The additive and extender for binder polymer should not have adverse effect on the earlier impregnated wood stabilizing chemical.

3. Polymers for Wood Impregnation and Their Characteristics

The acrylic polymers (emphasized here) for the dimensional stabilization of wood, have established utilization history as film forming constituents of floor polishes, coating, paints and filler coats for hardboard. Commercially acrylic esters are prepared by condensation of sodium alkoxides with methyl or ethyl acrylates. And, the water soluble analogues are prepared from above reaction by emulsion polymerization in presence of a suitable catalyst.

The thermoplastic series (Rohm and Haas 1980 & 1983) of water soluble acrylic polymers form films that are washable with water, but resistant to dirt pickup, abrasion, powdering and slipping. However, the dried films are removable with alkaline solutions.

On the other hand, the self-crosslinking series (Rohm and Haas 1982) of water soluble acrylic polymers are nonionic binders for nonwoven fibers. The analogues of this series ranges from soft to firm members which are easily blendable for controlling intermediate properties.

The self-crosslinking polymers on drying forms film that are resistance to UV light, (have greater promise for exposed wood like shakes and shingles) washing and drycleaning. The film thus formed are durable with high strength and dermitological safety. These polymers are suitable for durable and disposable application where blended with nonwoven fibers to give hospitals and medical products for end uses as personal hygiene, diapers, interlinings and house hold furnishings. The handling and working with water soluble acrylic polymers is much easier because of their good flowing and wetting behaviour which is free from noxious odors of solvents.

There are another series of reactive polymers (dimethylol compounds), having unexplored promises for wood stabilization. In broad sense, a chemical can crosslink with wood structure if it

has difunctional groups capable of reacting with the functional groups of wood. Also, it should have ability to penetrate into the cell-walls structure of wood. The analouges of dimethylol polymer meet both the requirements and are extensively used in texttile industries as crosslinking agents for cotton fabrics (Reinhardt and Kullman 1976, Rowland et. al. 1978, Welch and Margavio 1973).

In literature very little is said about the utilization of dimethylol or glyoxal compounds for the dimensional stabilization of wood. The objectionable hindrances are their crosslinking conditions which are acidic and the strengh of wood get deteriorated under these conditions. Secondly, the unproperly crosslinked glyoxal polymers get migrated to the surface of wood. However, the self crosslinking acrylic polymers are completely mixable with glyoxal based (cheaper and reactive) polymers. Both are acidic and their combination may be best suitable to enhance further applications. Very recently, the mixed formulations of glyoxal and self-crosslinking acrylic polymers are tried on wood. The result are very encouraging for the dimensional stabilization of wood and may be more suitable for the dimensional stability of wood particles.

4. Swelling and Shrinking of wood

Wood is well known for its tendency to shrinks and swells with the variation of moisture content. Such moisture

fluctuations (seasonal or environmental) near the vicinity of wood in service has major contribution to surface cracks or even structural failures. Although the impact of varying moisture cycles on exposed wood can be minimized with the help of suitable paints and surface coatings yet the improperly dried and dimensionally unstabilized wood is a bad selection as it has direct impact on the preformance of surface coatings.

4.1 Theory Behind Swelling and Shrinking:

The dried wood absorbs water which moves into cell walls leaving the lumens empty until such a time that the cell walls are saturated. In this process, the individual cellulose chains in the wood cell-walls pick up water and the internal space between the cellulose chains increases (Skaar 1972). The size of lumen generally remains unchanged and the entire expansion is essentially confined to individual cell-walls. The resultant impact of water absorption by wood is swelling to increase its dimensions (Stamm 1959 (a) & (b)).

On the other, wood starts shrinking when dried and the shrinking trend is a little bit differnt from the swelling. The main reason is the anisotropic nature of wood which never allow it to trace same path during a complete cycle of swelling and shrinking on wetting and redrying. Although the shrinking and swelling of wood above the fiber saturation point is not remarkable yet wood starts swelling right after dipping in water

from zero moisture content and this process continue till the wood is water logged (Maximum shrinking and swelling occur beween zero moisture and fiber saturation point).

The shrinking and swelling of wood with the change in moisture content is known as 'movement' which is 0.1-.15%, 3-5% and 5-15% in longitudinal, radial and tangential directions, respectively. The movement has general relationship with lignin content of the wood. To illustrate this fact, e.g. heart wood of a tree has more lignin than sap wood and if a block of wood is cut along the radial axis of the tree, shrinking pattern may be presented as in Fig.1.

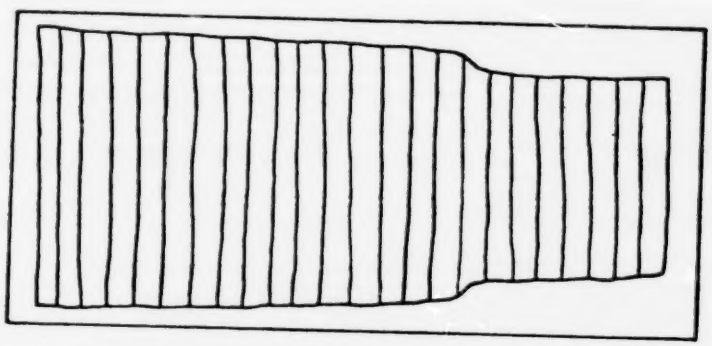

Figure 1 Shrinkage on drying.

4.2 Swelling of Wood in Polar Solvents:

Beside water, most polar solvents are absorbed by wood cell-walls, henceforth, capable of swelling wood by increasing the space between the cellulose chains within the cell walls (Skaar 1972). Such polar solvents can act as carrier for soluble

polymers that cannot penetrate the dried wood cell-walls. Polyethylene glycol (PEG-1000) molecule is a good example to support this fact. It has molecular weight 1000 and can only penetrate the cell wall in swollen condition (Stamm 1959 (a) & (b)).

4.3 Solvent Entrapment and Polymer Penetration into Wood:

Wood and cellulosic fibers are capable of entraping organic solvent molecules within the cell-wall capillaries. Mease 1933, Wiertelak and Garbaczowna 1935, Merchant 1954, independently treated wood and cellulosic fibers with solvents (dipping or solvent exchange) and found that the solvent could not evaporate completely even when wood is dried for a prolonged period at an elevated temperature above the boiling point of the solvent. The common accepted explanation for solvent entrapment is the size of capillaries pore within the wood structure that shrinks before the solvent has been completely evaporated. The capillaries become too small to allow the escape the entrapped sovent vapours.

Cote & Robinson 1968 and Smith 1980 used polar solvents and found that under certain conditions, the water soluble solvent used in water borne systems could be trapped in the cell-walls. Furuno and Goto 1973 worked on polymeric solutions and found that the penetration of methyl methacrylate was increased by 90% when polar solvent methanol was added to the treating solution.

Similarily, Smith 1969 and Robinson 1972 tried to impregnate wood with different molecular weight fractions of phenol-formaldehyde and recorded that the penetration of low-molecular weight fraction was much higher. Robinson 1972 tried non-polar systems to check the limit of molecular size and found that only molecules having a molecular weight of 250 can penetrate dry cell wall. It may be appropriate to mention here that the pigment and emulsion molecules are to large to penetrate wood cell-walls. Moreover, the non-polar solvent (their vehicals) shrinks the pore size of the capillaries, thus limiting the molecular size of polymer that can penetrate the cell walls.

DIMENSIONAL STABILIZATION OF WOOD PRODUCTS

Wood can be made dimentionally stabilized by several methods that prevent the entry of moisture into its internal structure. Some of them are;

1. Applying water resistant surface and internal coatings
2. Laminating the thin sheets of wood with binders
3. Reducing the hygroscopicity by chemical reaction.
4. Bulking with impregnating chemicals, and
5. Crosslinking with reactive type of chemicals.

The most promising methods with recent scientific and technology support is crosslinking (Stamm 1964, Nicholas and Barnes 1984).

Although the crosslinking chemicals have greater future for dimensional stability of wood yet most of them have adverse effect on strength properties of wood when the crosslinking with wood occurs in acidic conditions. The crosslinking polymer has better edge for penetration and crosslinking, when it is a part of formulation containing water and cosolvent. Such systems swell wood to facilitate the penetration of polymeric formulations into the swollen cell-walls and later on get deposited there on subsequent drying. Since, the impregnation of wood is done at room temperature, under neutral or mildly alkaline conditions, leaving very few chances for degradation or hydrolysis of treated wood.

EXPECTED RESULTS OF TREATMENT

The earlier work (Vasishth & Vasishth 1983, Vasishth 1983) showed that 2-3% polymer pickup by wood can increase the anti swelling efficiency (ASE, measure of dimensional stability) of wood by 50%. However, the polymer weight pickup by green wood, dipped for 24 hours in 8% polymer, is 6-8% and the wood treated under above conditions provide 30% overall anti swelling efficiency. Obviously, the size of wood sample has direct influence on the solution pick up. The cost estimates in Table are purely based on the above expected results. Where the dimensions of the samples are, (small = (2x4x10in) and large =

(1.5x3.5x91.2in)) in radial, tangetial and longitudinal directions, respectively.

COST ESTIMATION

The chemical cost is estimated by considering a few assumption given in Appendix.

Type of Polymer	Commercial Solution		Chemical Cost	
	Soild Content (%)	Price (1-5 drums) ($/Kg)	Solid ($/kg)	($/1000 MBF)
Thermoplastic	40.0	1.97	4.93	110.07*
		0.70	8.75	43.82**
Self-crosslinking	45.5	1.98	4.35	97.25
Glyoxal	44.0	1.65	3.75	83.79
Formulation P-1	44.3	1.72	3.87	86.49
Formulation P-2	45.2	1.91	4.23	94.54

N.B.:-

P-1 is a formulation of 20% Self-crosslinking acrylic polymer and 80% glyoxal polymer

P-2 is a formulation of 80% Self-crosslinking acrylic polymer and 20% reactive polymer

* Chemical cost of the polymer when it is used for wood impregnation in water solution with limited penetration.

** Chemical cost of polymer when its special formulation with cosolvent is prepared. 0.56% absorption by weight of this formulation (in small samples) imparts 30% anti swelling efficiency (ASE).

FUTURE SCOPE OF PROCESS & TECHNOLOGY

1. Application of water soluble acrylic polymers to upgrade wood is a barren field that needs immediate attention. The technology of the treatment process for wood impregnation is well known and available in literature (Richardson 1978, Bains 1976, Hunt and Garratt 1967).
2. Upon mixing water soluble acrylic polymers with preservatives and fire retardants under certian pH, the blend have wide scope (unexplored and promising) where the polymer act as fixatives. Some of the blends of polymer with Timbor and 3-iodo-2propynl butyl carbamate (IPBC), Kathon LX and toxic salts of copper and zinc (commercial wood preservatives for controlling sap stain and to increase service life) showed very encouraging results. Although the Timborized wood have very good reputation in foreign market yet the preservative is leachable from treated wood. It appears from the perliminary investigations that these blends have some catches as the penetration of polymers into wood is strongly influenced by the loaded additives. Therefore the pressure treatment might have better future for proper chemical distribution in treated wood.
3. A blend formulations of glyoxal and self crosslinking acrylic polymer has been used for commercial trials for oriented strand board. The results are very encouraging and need further investigations.

4. As a general rule decayed timber is nothing but fire wood. However, it can be made desirable by valuable carving, ornamental work or antique panelling, provided the decayed part have sufficient strength to be intact. On dip treatment, the decayed wood absorbs more solution than healthy wood under same treatment and the additional absorbed solution compensated the fragilness of decayed wood on drying. This technique of decayed wood treatment may be the best step to utilize the decayed aspen for ornamental work.

OVERVIEW

The appropriate treatment of wood (healthy or decayed) with acrylic or glyoxal polymers improves the quality of wood by superimposing most of its defects and increasing the dimensional stability, the best and most economical method of improving the service life of wood.

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APPENDIX

(a) Volume of one stud (1.5x3.5x91.2in) = 3.336 MBF
= 7846 cc
Volume of small sample(2x4x10in) = 1311 cc
Oven dried weight of each sample = 498 g

Density of wood = 0.38 g/cc

No. of stud/1000 MBF = 300
Weight of each stud = 2.981 Kg
Weight of 1000 MBF = 894 Kg

(b) Weight of polymer for
50% Anti swelling efficiency = 22.35 kg/1000 MBF

Weight of polymer for
30% Anti swelling efficiency = 5.008 Kg/1000 MBF